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COUNTY ATLAS SERIES
ATLAS C-12, PART A
Plate 3—Surficial Geology and Thickness of Quaternary Sediments

SURFICIAL GEOLOGY AND THICKNESS OF QUATERNARY SEDIMENTS

By

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1998

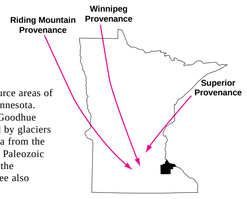


Figure 1. The major source areas of glacial deposits in Minnesota. Almost all the till in Goodhue County was deposited by glaciers that entered Minnesota from the northwest, picking up Paleozoic carbonate rocks from the Winnipeg lowland. See also Table 1.

Table 1. General characteristics of glacial deposits in southeastern Minnesota.

[See also Figure 1. Lithology (rock type) was determined from samples of 1–2-millimeter-size rock particles in till and outwash.]

PROVENANCE	RIDING MOUNTAIN	WINNIPEG	SUPERIOR
TILL TEXTURE	Mostly loamy	Loamy to clayey	Loamy to sandy
TILL COLOR			
Oxidized	Yellow to olive-brown	Yellow-brown	Reddish-brown
Unoxidized	Gray	Gray	Grayish-red
ROCK TYPES IN TILL AND OUTWASH			
Precambrian			
Black to gray-green rock	Uncommon	Uncommmon	Common
Red sandstone & felsite	Absent to rare	Rare to uncommon	Uncommon to common
Paleozoic carbonate	Common	Common to abundant	Uncommon to common
Cretaceous			
Gray shale	Uncommon to abundant	Absent to rare	Absent
Limestone & calcareous shale	Rare	Rare to uncommon	Absent

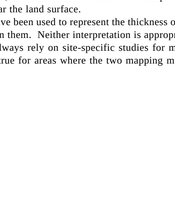
Digital base modified from 1990 Census TIGER/Line Files of U.S. Bureau of the Census (source scale 1:100,000); county border files modified from Minnesota Department of Transportation files; digital base annotation by Minnesota Geological Survey

Universal Transverse Mercator Projection, grid zone 15
1927 North American Datum

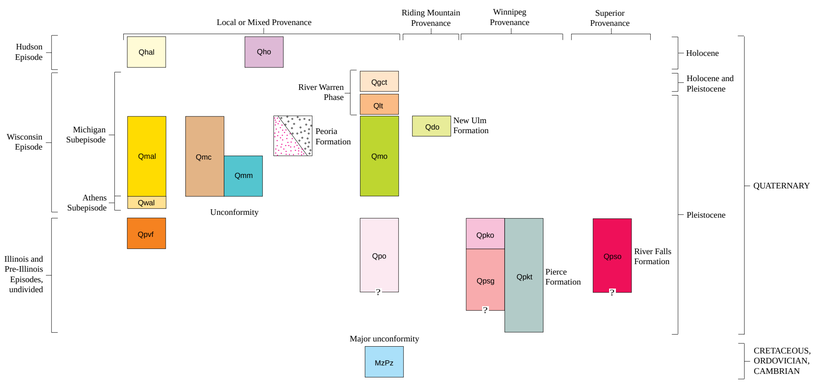
SCALE 1:100 000
1 0 1 2 3 4 5 MILES
1 0 1 2 3 4 5 6 7 8 KILOMETERS

Surficial geology by H.C. Hobbs; field mapping, 1996–97
Thickness of Quaternary sediments compiled by D.R. Setterholm

GIS compilation and cartography by Joyce Meints and Philip Heywood



CORRELATION OF MAP UNITS



DESCRIPTION OF SURFICIAL MAP UNITS

NONGLACIAL DEPOSITS

Qho **Organic deposits (Holocene)**—Peat and organic-rich silt and clay deposited in poorly drained depressions. Most organic deposits in Goodhue County are in floodplains, especially of the Mississippi River, and are included in the alluvium map unit (Qhal). Only two delineations of organic deposits are shown: one in an outwash plain in the northwestern part of the county (sec. 5, T. 111 N., R. 18 W.), and one in the Frontenac diversion channel (T. 112 N., R. 13 W.). The Frontenac channel deposit has been partly filled and drained. Organic deposits also are present in the middle of the Wacouta diversion channel, east of Red Wing, but the delineation is too narrow to portray at the map scale.

Qhal **Alluvium (Holocene)**—Deposits of modern streams; channel sand and gravel overlain by overbank silt and clay in floodplains; peat and organic-rich clay in places.

Qwal **Older alluvium (Pleistocene)**—Shown only on cross section C–C' (Plate 4). Deposited by streams before the period of hillslope instability of the Michigan Subepisode. Sand with some gravel (mostly chert and a few erratics); highly oxidized and leached.

DEPOSITS INDIRECTLY RELATED TO GLACIATION

Qgct **Sand and gravel of Grey Cloud terrace (Holocene and Pleistocene)**—Deposits of River Warren. Coarse, clean sand and gravel derived from the Mississippi valley train (map units Qmo and Qpo) and reworked by the swift water of River Warren. Depth of reworking uncertain. Unit consists of more than one level, separated by scarps. Normal terrace elevations in the county, 680–720 feet.

Qlt **Sand and gravel of Langdon terrace (Pleistocene)**—Deposits of River Warren as described above. Normal terrace elevations in the county, 740–780 feet. The surface of both the lower (Grey Cloud) and upper (Langdon) terraces slopes gently in the same direction as the slope of the bed of the Mississippi River, from northwest to southeast.

Qmal **Alluvium of Michigan Subepisode (Pleistocene)**—Deposited by braided streams and sheetfloods in valleys. Predominantly sand, but unit includes some gravel, finer sediment, and, in valleys adjacent to the Mississippi River, backwater silt. Unit forms terraces above the modern floodplain that range from only slightly higher than modern floodplain levels to over 100 feet higher. Unit also underlies modern alluvium in many places (see cross sections E–E' and F–F' on Plate 4). Where both units are exposed but the valley is too narrow to map each, the widest unit is mapped.

Qpvf **Valley-fill sediment (Pleistocene)**—Shown only in section A–A' (Plate 4). Deposited by slopewash and stream sediment in an overdeepened valley. Partly fills the Strusz diversion channel (sec. 34, T. 113 N., R. 15 W.); may underlie alluvium of Michigan Subepisode (map unit Qmal) in other diversion channels. Where sampled, the valley-fill sediment is fine to very fine sand, highly oxidized but calcareous.

Qmc **Colluvium (Pleistocene)**—Hillslope deposits derived from bedrock and from loess upslope. Typically consists of two subunits: (1) a rocky lower unit of angular carbonate clasts in a silty to sandy matrix, which is overlain by (2) a unit, primarily composed of silt, that contains a few carbonate clasts. The composition of the lower unit reflects the bedrock upslope; the upper unit is largely reworked loess. Both strata are thin (less than 5 feet) on the upper parts of the slope; they thicken downslope to a maximum of about 30 feet. Exposure of bedrock is common, especially on the upper parts of slopes. On the cross sections (Plate 4), the colluvium map unit is only shown on the lower parts of the slopes, where it is thickest. On the ground, colluvium and bedrock exposures form an intimate association, which can only be roughly captured on the map.

Qmm **Mudflow sediment (Pleistocene)**—Deposited on footslopes of valley sides, generally downslope from outcrops of Decorah Shale (see Plate 2 for description and distribution of the Decorah). Unbedded gray clay or clayey diamicton; contains a few pebbles, most of which are fossil hash from the Decorah, although a few are glacial erratics reworked from older glacial deposits. The unit typically is present near the contact between colluvium and alluvium in patches too small to delineate at the map scale. The actual mudflow sediment is commonly covered by a few feet of sand or silt (map unit Qhal or Qmal).

Peoria Formation (Pleistocene)—Windblown (eolian) sediment. Loess, the dominant facies, was deposited as dust from the air. Eolian sand was blown along the ground.

Loess—Uniform unbedded silt to very fine sand, mixed with some clay. Overlies unmapped eolian sand in places. Unit is 5–15 feet thick where shown on the map. Thin unmapped loess is present almost everywhere over the county, except on modern alluvium (map unit Qhal), which in turn is composed mostly of reworked loess. Pattern omitted on colluvium.

Eolian sand—Unbedded fine to medium sand. Unit is 5–10 feet thick where shown on the map. Thinner patches are not mapped.

GLACIAL DEPOSITS

Qmo **Mississippi valley train (Pleistocene)**—Outwash deposited by meltwater from the combined ice lobes of Minnesota and western Wisconsin; its provenance is mixed Superior and Riding Mountain (Fig. 1; Table 1). Gray shale from the Des Moines lobe is sparsely present in places; its abundance has been greatly reduced in transit. Chiefly sand and gravel, but finer grained facies were deposited in quieter backwater areas, as illustrated on cross section I–I' (Plate 4).

Qpo **Older Mississippi valley train (Pleistocene)**—Shown only on section I–I' (Plate 4). Analogous to unit above (Qmo) but older; oxidized and partly leached.

Qdo **Outwash of the New Ulm Formation (Riding Mountain provenance) (Pleistocene)—** Deposited by meltwater streams from the Des Moines lobe, west of Goodhue County. Chiefly sand and gravel with some beds of silt. Rock types represented in the outwash are dominated by limestone, dolostone, and granite; unit also contains small amounts of gray shale. In addition to the areas where it is mapped at the surface, the outwash is present in places under the alluvium in the valleys of the Cannon and the North Fork Zumbro Rivers (see cross section B–B' and H–H' on Plate 4).

Qpso **Outwash of the River Falls Formation (Superior provenance) (Pleistocene)**—Deposited by meltwater. Chiefly sand and gravel; in places it contains a gravelly clay B soil horizon at the top of the deposit. Deeply leached in most places but contains some carbonate clasts below the leached zone. Present in valleys and in low areas on the uplands. May underlie alluvium in diversion channels. No till of the River Falls Formation was observed or mapped. Instead, in places within the area formerly covered by the ice lobe, a lag of Superior-provenance pebbles, cobbles, and boulders is present on the surface of the bedrock. Soil development in this "old red" drift indicates a pre-Michigan age; these deposits have traditionally been considered Illinoian (Leverett, 1932).

Pierce Formation (Winnipeg provenance) (Pleistocene)—Till of this formation has been called "old gray" till. As defined in Wisconsin (Mickelson and others, 1984), the Pierce Formation is stratigraphically below the River Falls Formation, but as mapped here, it includes some material that may belong to the Illinois Episode (map unit Qpko and a little Qpkt).

Qpko ***Outwash***—Deposited by meltwater streams from an ice lobe to the west. The unit includes only the most recent outwash of the Pierce Formation; it forms a terrace higher than the surfaces of alluvium of the Michigan Subepisode (unit Qmal) and New Ulm outwash (unit Qdo) in the valley of the North Fork Zumbro River. Soil development on the terrace suggests a pre-Michigan age for the glaciation. Chiefly sand and gravel; rich in carbonate clasts below the leached zone. In contrast to New Ulm outwash, this unit contains no shale.

Qpkt ***Till***—Unsorted, unstratified drift deposited by several pre-Wisconsin glaciations (see Plate 4 for additional information). Typically loam to clay loam that contains subangular to rounded clasts of both local and erratic rocks (mainly the latter). Mapped where generally thicker than 5 feet; thinner patches over bedrock are not mapped.

Qpsg ***Glaciofluvial deposits***—Deposited by meltwater streams from old glaciations. Unit is included in the Pierce Formation because most of it is mostly of Winnipeg provenance. Includes both outwash and ice-contact stratified drift. Chiefly sand and gravel with minor beds of silt and clay in places. Strongly weathered from the top to a depth of several feet to as much as 15 feet. Calcareous material is present beneath the weathered zone in places. The unit is present in patches within the uplands as remnants of more extensive deposits. Includes deposits covered by a thin layer of till or by a lag of cobbles and boulders from a till.

BEDROCK

MzPz **Bedrock, undivided (Cretaceous, Ordovician, Cambrian)**—Bedrock outcrops and bedrock that is generally within 5 feet of the surface, exclusive of loess. Includes scanty and widely scattered deposits and weathering residuum of Cretaceous age, as well as more recently weathered bedrock. Solid bedrock, therefore, is deeper than 5 feet in many parts of this map unit.

DESCRIPTION OF MAP SYMBOLS

Geologic contact—Most are approximately located; less precise where covered by thick eolian sediment.

Ice margins of the Illinois Episode (?)—Ticks point toward the ice. Inferred from scattered or indirect evidence.

River Falls

Pierce

Abandoned stream beds cut into bedrock—Two types are recognized: meander scars and diversion channels.

Meander scar—Relatively distinct; eroded and obscure. Ticks point downslope. Inner hill, if present, is not hachured.

Meander scars were formed by an earlier phase of the stream, at a higher level within the same valley. As the stream shifts its course during downcutting, some of its abandoned meander loops are left behind; they are gradually obliterated by slope erosion and small tributary streams. Although classified as either relatively distinct or as obscure, there are many gradations in the degree of erosion. The older, more obscure scars are generally higher above stream level.

Diversion channel—Relatively distinct; eroded and obscure. Ticks point downslope.

Most diversion channels cut across the modern drainage network. A few of them connect two parts of the same valley (cross section F–F' on Plate 4). Diversion channels are formed by glaciation in two ways: they may be carved by meltwater diverted around the glacier, or a pre-existing valley is partly blocked by glacial deposits, diverting the postglacial stream into a new course.

Scarp within outwash—Ticks point downslope. Mapped only in New Ulm outwash (map unit Qdo). Represents the edge of a channel or the remains of an erosion event that affected only part of the unit. Geologic contacts between adjacent fluvial units (outwash, terrace deposits, alluvium) are also commonly scarps.

General direction of fluvial transport—Shown on outwash and terrace units. Actual flow directions varied with time and were more complex than shown.

50 **Line of equal thickness of Quaternary sediments**—Contour interval 50 feet. The 100-foot contour line has been interrupted in areas of very steep slope.

DETERMINING THE THICKNESS OF QUATERNARY SEDIMENTS THROUGH COMPUTER MODELING

Contours representing the shape of the bedrock surface were drawn by hand on the basis of bedrock elevations from outcrops and water-well records and on geomorphic inferences. The contours were then entered in a digital Geographic Information System (GIS). That surface was mathematically compared to a digital-elevation model of the land surface prepared by the U.S. Geological Survey. The land-surface model represents the land surface with a single elevation value for each 90-meter-square parcel in the county. The space between the land surface and the bedrock surface is occupied by Quaternary-age materials. The thickness of these materials was derived by calculating the difference in elevation between the models of the land and bedrock surfaces. The thickness values were then contoured by the computer. The resulting map was checked against known locations of outcrops and information on depth to bedrock from well records; contour lines were modified, where necessary, to agree with this information. Most discrepancies are near steep escarpments where a single elevation value cannot adequately represent elevation for a 90-meter cell.

Because the method compares a high-resolution (detailed) model of the land surface with a low-resolution model of the bedrock surface, the resolution of the resulting thickness map was adjusted by removing all contoured areas smaller than about 500 feet in diameter. These small areas suggested a level of accuracy that is not actually supported by the data.

One of the surficial map units (MzPz) also addresses the thickness of glacial drift. The map unit, derived in part from soil characteristics, is used in areas where the interpretation of the surficial geology indicates bedrock is at or near the land surface.

Because two methods, both imperfect, have been used to represent the thickness of Quaternary sediments, areas of disagreement exist between them. Neither interpretation is appropriate for site-specific information, and map users should always rely on site-specific studies for more accurate information on thickness. This is especially true for areas where the two mapping methods result in different interpretations.

GEOLOGIC EVENT TERMINOLOGY

The terminology used for correlating map units follows a new system that emphasizes correlation by event, rather than by years (Hansel and Johnson, 1996). The new system replaces the Wisconsinan Stage with the Wisconsin Episode; the late Wisconsinan glaciation becomes the Michigan Subepisode. Sediments of the River Warren Phase were deposited after ice had left the area, though the ice continued to influence sedimentation by damming large glacial lakes that overflowed down the Mississippi River. Postglacial sediments of the Hudson Episode look much like sediments that are being deposited today.

The transition between adjacent event units (for example, between the Michigan glaciation and the postglacial Hudson Episode) did not occur at the same time wordwide. The time differences are negligible within a county, so correlation by radiometric dating is theoretically possible, but very few such dates exist for sediments in Goodhue County. Units are correlated by physical characteristics of the sediment, stratigraphic position, and proxy data on elapsed time, such as soil development. For example, soils formed on deposits of the Michigan Subepisode show a normal degree of development compared with Minnesota soils in general, most of which formed on Michigan Subepisode deposits. Older sediments commonly are capped by remnants of older soils having a stronger degree of soil development, including one or more of the following: deeper leaching, redder or more intense brown oxidation colors, thicker, more clayey B horizons, and more intense weathering of rock fragments. Complete profiles of these older soils are rarely found; erosion commonly has removed the A horizon (topsoil), part or all of the B horizon (subsoil), and, in some places, the entire soil profile. In these places, subsequent soil development begins anew, as if on freshly deposited material. Remnants of old soils are taken as evidence that the entire stratigraphic unit is pre-Michigan.

PROVENANCE OF GLACIAL DEPOSITS

Glacial provenance refers to the area from which a particular lobe or sector of a glacier derives the bulk of its sediment, or a distinctive, recognizable component of it. Table 1 summarizes the distinctive features of three provenances known from Goodhue County. The characteristics of tills of Riding Mountain and Superior provenance are included for completeness, even though the only tills mapped in the county are of Winnipeg provenance. Light grains of granite and quartz are common to abundant in all samples and therefore are not included in the table.

Almost all the till in Goodhue County was deposited by glaciers that entered Minnesota from the northwest, picking up Paleozoic carbonate rocks from the Winnipeg lowland (Fig. 1). Some samples of till are highly oxidized and leached, or contain mostly local rock fragments, or both, so their provenance is not easily determined. Several till sheets have been recognized in the western part of the county (Plate 4). They all have the general characteristics of Winnipeg provenance, but can be distinguished by subtle differences.

The defining characteristics of Superior provenance (red, sandy till rich in red and black Precambrian rock fragments) were acquired as the ice passed through the basin of Lake Superior (Fig. 1). Superior ice of the last glaciation did not extend as far southeast as Goodhue County but contributed a great deal of outwash to the Mississippi valley train (map unit Qmo). The River Falls Formation was deposited by the most recent advance to reach the county. No till remains of the River Falls Formation and only small patches of outwash. Some sediment may have been buried by younger deposits. The rest has been eroded away, leaving only some of the larger rocks behind to show that it was once there.

Older deposits of Superior provenance have been observed, but they are extremely scanty and not mappable. However, the gray tills have incorporated some of the red debris from these earlier Superior-lobe advances. Almost every sample of sand from gray till contains at least one "red" grain; most samples contain 1–2 percent of these reds. Some blocks of Superior-provenance till have apparently been incorporated into the gray till, but only partly disseminated. A soil boring in Vasa Township penetrated several feet of reddish sandy till, overlain and underlain by gray till.

The Red River valley–Winnipeg lowland is bounded on the west by the Pembina–Riding Mountain escarpment. Glaciers that passed from west to east over this escarpment brought large amounts of gray Cretaceous shale to Minnesota. The Des Moines was the only glacial lobe of Riding Mountain provenance in southeastern Minnesota. Although it did not enter Goodhue County, its meltwater carried outwash down the valleys of the Cannon and Zumbro Rivers.

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Goodhue County